STRUCTURES IN SCHIST, TAWONGA, VICTORIA, AUSTRALIA

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Abstract

Foliations and folds in chlorite-quartz-albite schists from Tawonga, N.-E. Victoria, are described. Micro-structural analysis has established geometric and gentic relationships between schistosity and F1 folds; and between kink banks, crenulation cleavage, and F2 folds.

Introduction

The northern slopes of the Symmond's Ck valley, near Tawonga, form the footwall of the Tawonga Fault. The rocks are deeply weathered, covered by hill-slope debris and alluvium, and therefore exposures are poor. In the floor of the valley, about 3 miles upstream from the junction of Symmond's Ck with the Kiewa R., chlorite-quartz-albite schists are sufficiently well exposed to permit a study of the structure of these rocks: the lowest grade of crystalline schists occurring on the western margin of the Metamorphic Complex, within the Complex itself.

The Symmond's Ck.—Tawonga Gap area lies within the zones of the Tawonga Fault and the West Kiewa Thrust. Its geology is far from simple. Immediately S. of the exposures described in this paper the Tawonga Thrust plane is exposed, and the chlorite-quartz-albite schist is overlain by crushed brecciated quartz feldspar-sillimanite gneiss (Fig. 1). Immediately to the N. is a complex belt of gneiss, high and low-grade schists, mylonites, greywackes and slates, which obviously represents a major crush zone.

The work described in this note established, for the first time, the existence of two generations of folds on both microscopic and mesoscopic scales, in the crystalline schists. Previously, multiple folding had been recognized in the sediments bordering the Metamorphic Complex, but no evidence of such deformation had been found in the Complex itself (Beavis 1963, 1964, 1965).

The help in the field of Mrs. Joan Beavis and Mr. F. Himing is gratefully acknowledged.

Mesoscopic Structure

The schists of the Symmond's Ck area appear to have a single foliation, S1, emphasized by laminae of chlorite alternating with laminae composed essentially of quartz and albite. This foliation is crenulated, the axial surfaces of the small folds having a steep dip and an axial surface separation of 1 to 2 cm. The axial surfaces do not constitute a prominent foliation on the mesoscopic scale. The hinges of the crenulations form S.-E. and N.-W. plunging linear structures in the schistosity, while on the schistosity planes there is occasionally visible a deformed colour banding lineation which appears to represent a trace of original bedding.

Foliation S1 is sub-parallel to the surfaces separating thick pelitic layers from thick arenaceous layers; these surfaces have been interpreted as original bedding

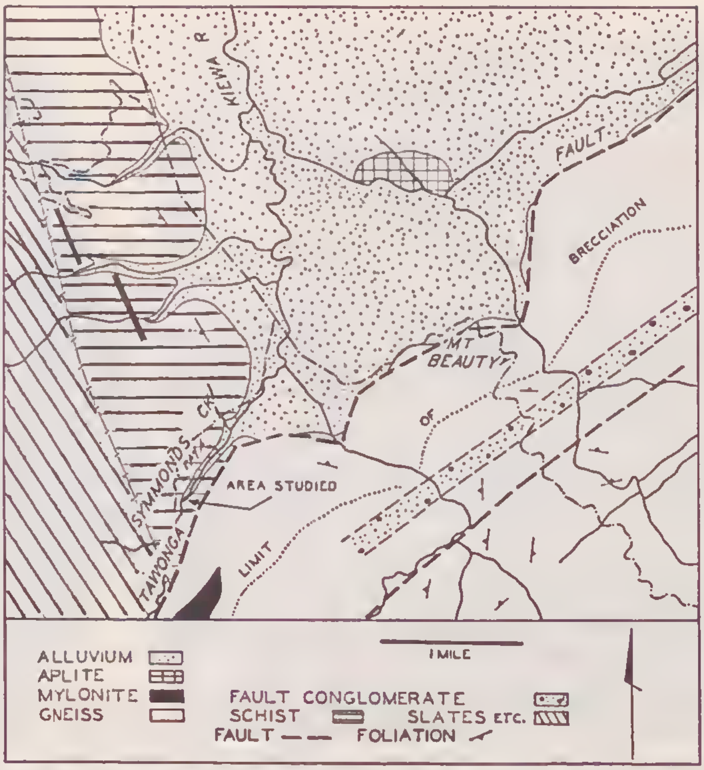

FIG. 1—Locality map, showing geology in the area studied.

planes (So). The bedding planes, as well as the foliation, have been deformed into relatively large mesoscopic folds, whose profiles can be seen in the road cutting. The folds may be quite sharp and tight, or may be open. Since the foliation S1 is a form surface of the folds, they are interpreted as second generation F2 structures.

Microscopic Structure

Because of poor outcrops and deep weathering, little can be learned of the structure of the schists on a mesoscopic scale. A series of oriented specimens was faced for microscopic examination, and a series of oriented thin sections were prepared for qualitative and quantitative microscopic study.

(i) FOLIATIONS. With microscopic examination, three sets of surfaces can be recognized in the schists: bedding (So); schistosity (S1) emphasized by a lithological layering; and kink bands with rare crenulation cleavage (S2). The kink bands and crenulation cleavage are restricted to pelitic laminae. The lithological layering, consisting of thin discontinuous laminae or quartz and albite, alternating with thicker, more continuous laminae of chlorite with fine needles of quartz, is essentially parallel to the fine schistosity of the chlorite laminae formed by the preferred orientation of the chlorite flakes and quartz needles. The thicker quartz-albite layers show a quite definite and consistent gradation of grain size, and in some quite specific domains are cut by the schistosity. These facts suggest that the lithological layering represents original bedding, almost completely transposed by the schistosity S1, into the plane of schistosity. This conclusion is confirmed by the existence of microfolds (Fig. 2) in the quartz-albite laminae, and to a lesser extent in the chlorite laminae, the axial planes of which are the schistosity S1. These microfolds are F1 structures. After transposition, the laminae were subsequently deformed by a second folding, the small folds so formed being kink bands, sometimes with crenulation cleavage as axial surfaces. On the prepared faces, and in thin section, the kink bands and crenulation cleavage form a distinctive foliation S2 but this cannot be readily distinguished in the field.

FIG. 2—F1 folds in quartz-albite lamina.

As noted above, the kink bands are restricted to the chlorite layers. Their boundaries are rarely planar, but have a distinct curvature: moreover, within any one lamina the dip of kink bands may vary through a range of 50° (Fig. 4). Where they are interrupted by quartz-albite laminae, the kink bands are refracted by as much as 30°, after which they gradually curve back to a normal attitude. Curvature of the kink bands generally appears to be associated with gradation in texture of the chlorite. The width of kink bands varies between 0·1 and 2·0 mm but the width of an individual band is by no means constant. Several bands may converge to form a single wide band; a band may decrease in width and gradually die out, or it may terminate quite sharply. Sometimes, with narrowing, the kink bands pass into a crenulation cleavage, the transition being achieved by increasing rotation of the chlorite flakes.

FIG. 3—Styles of kink bands.

In a recently published work, Dewey (1965) recognized four geometric classes of kink band, each with unique characteristics, in whose formation strains and mechanisms differed markedly. Of Dewey's types, two occur in the rocks under discussion: segregation kink bands, and shear kink bands. In some isolated instances, the former occur as *en echelon* second-order sets, usually in antiformal hinge zones. Apart from this, there is no restriction on the distribution of the two types which may occur as adjacent bands (Fig. 3). The segregation kink bands are reverse types with kink planes developed only rarely; these are never planes of total strain discontinuity. Fine accumulations of quartz may occur along the kink planes. The shear kink bands are both normal and reverse; the kinks have well rounded hinges, and the style is 'similar'. It is this type which passes into crenulation cleavage.

(ii) FOLDS. Microscopically, two generations of folds can be distinguished: the first-generation F1 folds have been obliterated to a large degree by transposition, but a few remnant F1 hinges have been preserved. The form surfaces of these folds is So, with S1 forming the axial surfaces. The second-generation folds, F2, occur on three scales: the microscopic kink bands in S1; the mesoscopic crenulations in the lithological layering with S2 as axial surface, and with axial plane separation of 1-2 cm; and large mesoscopic folds in So and S1, with axial plane separation of up to 100 ft. The microscopic F1 folds are more readily recognized in the quartz-albite laminae, where the hinges are tight, and the limbs drawn out to the thickness of a single grain. The hinge zones are thickened, but maximum thickness occurs to one side of the hinge proper. Often, these folds have been completely closed, so that the two limbs are in contact along the axial surface. The total effect of this is to produce a localized thickening of the lamina.

The F2 microscopic folds include kink bands, but if this style is excluded it can be stated that the F2 folds have for the most part rounded hinges, although some are sharp and even cuspate. The geometry approaches that of the ideal similar style fold (Fig. 4). Anomalous thickening of the limbs of F2 folds is associated with F1 fold hinges.

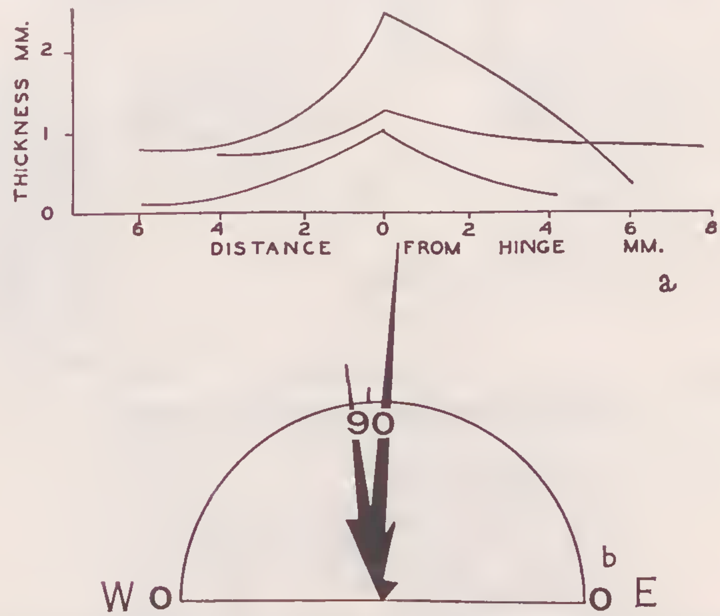

FIG. 4—a. Geometry of chlorite lamina indicating 'similar' style of folds.
b. Dip of kink bands in a chlorite lamina. Radius of circle represents 10 bands.

(iii) MICROSTRUCTURE OF THE QUARTZ-ALBITE LAMINAE. Qualitative examination of the quartz-albite laminae suggests a dimensional orientation of the quartz and albite grains (Fig. 6a). Dimensional orientation, however, depends on the thickness of the layer; for the thicker layers, the long axes and long edges of quartz and albite grains are parallel to S2 and produce a crude foliation. In the layers which are only one or two grains thick any dimensional orientation developed is such that the long axes of grains are parallel to S1 (Fig. 6b). This evidence indicates that, although there was no excessive elongation of the quartz, both F1 and F2 deformations involved some rotation of the quartz and albite grains.

Orientation of [0001] quartz was determined in the quartz-albite laminae and shows a high degree of homogeneity, the only departure from the standard pattern occurring in F1 fold hinges.

Fig. 5—F2 folds in chlorite-quartz albite schist.

Fig. 6—Preferred dimensional orientation of quartz in quartz albite laminae.
a. Thick lamina: long axes lie parallel to S2.
b. Thin lamina: long axes lie parallel to S1.

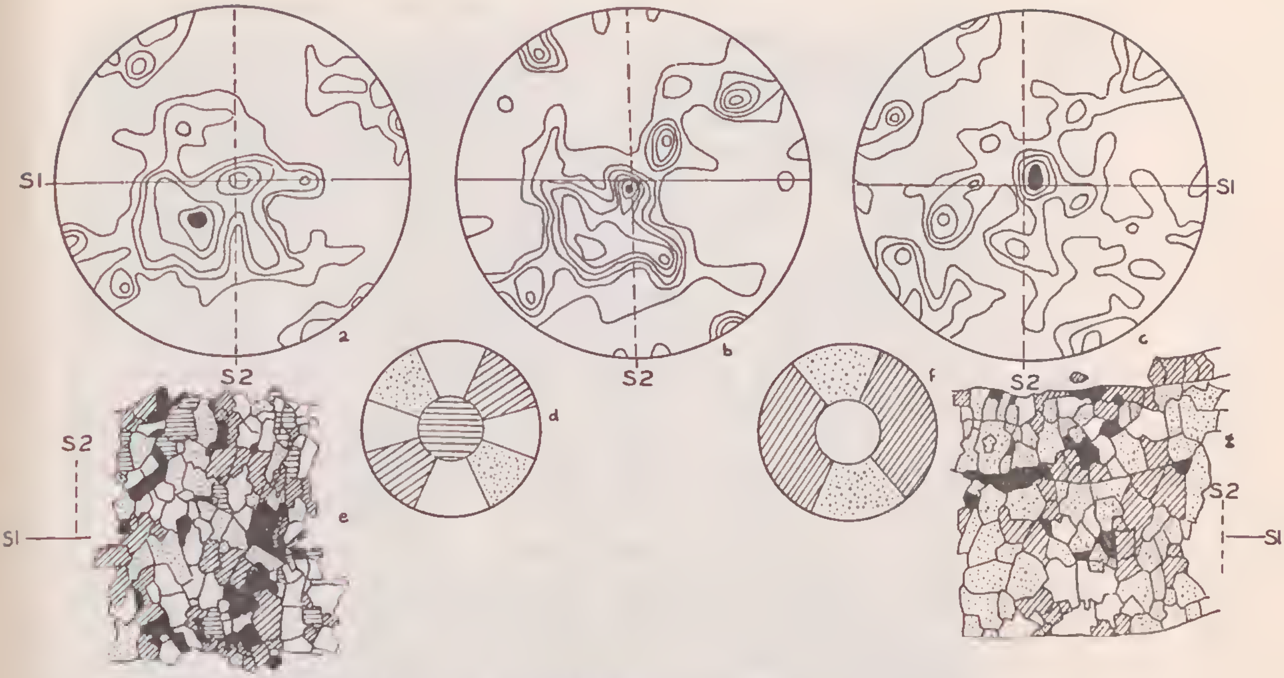

FIG. 7—a. 127 [0001] quartz in quartz albite lamina forming limb of F2 fold. Contours 1, 2, 3, 5, 10, 15%
b. 112 [0001] quartz in quartz albite lamina at hinge of F2 fold. Contours 1, 2, 3, 4, 5, 7, 9%
c. 93 [0001] quartz in quartz albite lamina at hinge of F1 fold.
d. Direction groups of figure 7a.
e. A.V.A. of area analysed in figure 7a.
f. Direction groups of figure 7b.
g. A.V.A. of area analysed in figure 7b.

Three of the analyses are shown on Fig. 7. Deformation lamellae are present in a few quartz grains. These appear to be symmetrical about S2 and have orthorhombic symmetry, but, since only 23 grains showed lamellae, the data are inadequate for further discussion. Fig. 7a shows the orientation of [0001] quartz in the limb of an F2 fold; Fig. 7b, in the hinge of an F2 fold; Fig. 7c, in the hinge of an F1 fold. All diagrams have two partial girdles oriented symmetrically with respect to S2. In addition, the diagram for the F1 fold shows a girdle lying in S1.

A.V.A. of the two domains of Fig. 7a and 7b are shown respectively in Fig. 7d and 7e; and 7f and 7g. This analysis suggests two domains, one lying in S1 and one in S2. If this interpretation is correct, the orientation of the quartz is the combined result of the F1 and F2 deformations.

Discussion

The evidence is quite conclusive, that the chlorite-quartz-albite schists at Symmond's Ck, Tawonga, have been subjected to two folding deformations. The mechanism of the F1 folding was by slip or flow on S1 with a limited amount of slip on So. Movement on S1 was extreme, leading to an almost complete transposition of So into S1. At the same time, deformation was accompanied by considerable recrystallization. It would be expected that the work of Dewey on kink bands (op. cit.) would lead to the use of these structures to determine the mechanism of the F2 folds. Dewey reasoned that segregation kink bands were formed by flexure with dilation normal to the band, indicating rapid deformation at a high structural level. Shear kink bands on the other hand were stated to indicate slow plastic distortion. This apparently anomalous situation in the Tawonga schists, where both types occur together, doubtless arises because Dewey argues from idealized mathematical models which do not always approach actual physical conditions.

The evidence is clear, nonetheless, that the F2 folding involved a flexural slip mechanism, although it is not possible to assess the tectonic environment. Active planes of movement which would have formed had folding been by slip or flow on S2 are so weakly developed that this mechanism cannot be regarded as having played a significant role.

Acknowledgements

I wish to thank the University of Melbourne for payment of part of the cost of publication of this paper.

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Description of Plate

Plate 11

Fig. 1—Photomicrograph (× 20) of schist showing kink bands (S_2) in S_1.